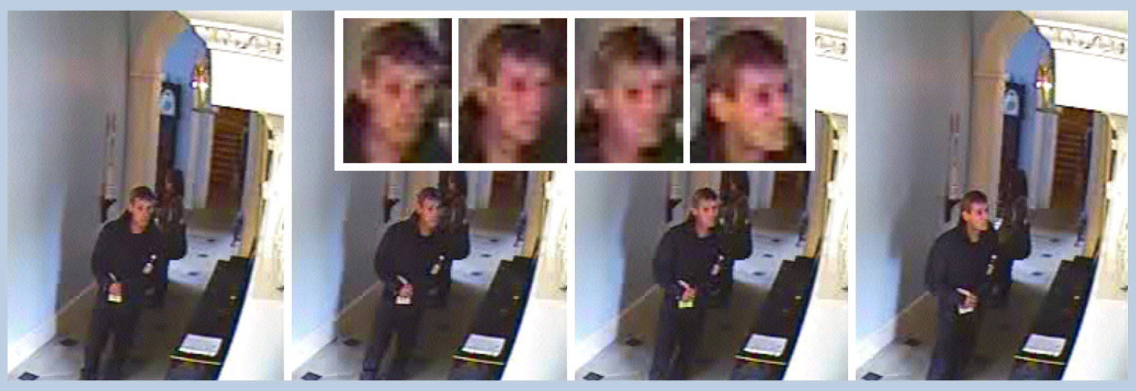
CCTV Revisited: Face Analysis Under Challenging Conditions

Anil Bas and William A. P. Smith
Department of Computer Science, University of York

Problem

Motivation: It is difficult to obtain meaningful data from poor resolution images, especially given challenging conditions such as motion blur, saturation, sensor noise, pose and illumination changes. Although some studies provide questionable routes to analysing this sort of poor input, thus far very little research has been conducted on such difficult data.



Hypothesis: Landmarks (reference points) and edges provide a strong cue for estimating 3D face shape from 2D images.

Novelty: We adapt the ICP algorithm for use in fitting a 3DMM to image edges automatically. This is the first approach that uses hard model/edge correspondences and leads to an algorithm that is both efficient and robust.

3D Morphable Model

A 3D Morphable Model is a deformable mesh whose shape is determined by the shape parameters $\alpha \in \mathbb{R}^S$. Shape is described by a linear model learnt from data using Principal Components Analysis (PCA). So, the shape of any object from the same class as the training data can be approximated as:

$$\mathbf{s}(\alpha) = \mathbf{P}\alpha + \bar{\mathbf{s}}, \quad (1)$$

where $\mathbf{P} \in \mathbb{R}^{3N \times S}$ contains the S principal components, $\bar{\mathbf{s}} \in \mathbb{R}^{3N}$ is the mean shape and the vector $\mathbf{s}(\alpha) \in \mathbb{R}^{3N}$ contains the coordinates of the N vertices, stacked to form a long vector: $\mathbf{s} = [x_1\ y_1\ z_1\ \ldots\ x_N\ y_N\ z_N]^{\mathrm{T}}$.

Algorithm

Algorithm 1: Basic algorithm employed to fit a 3D Morphable Model to a 2D image using known correspondences.

Data: 3D Morphable Model, 2D image, Reference points
Result: Face model fitted to 2D image

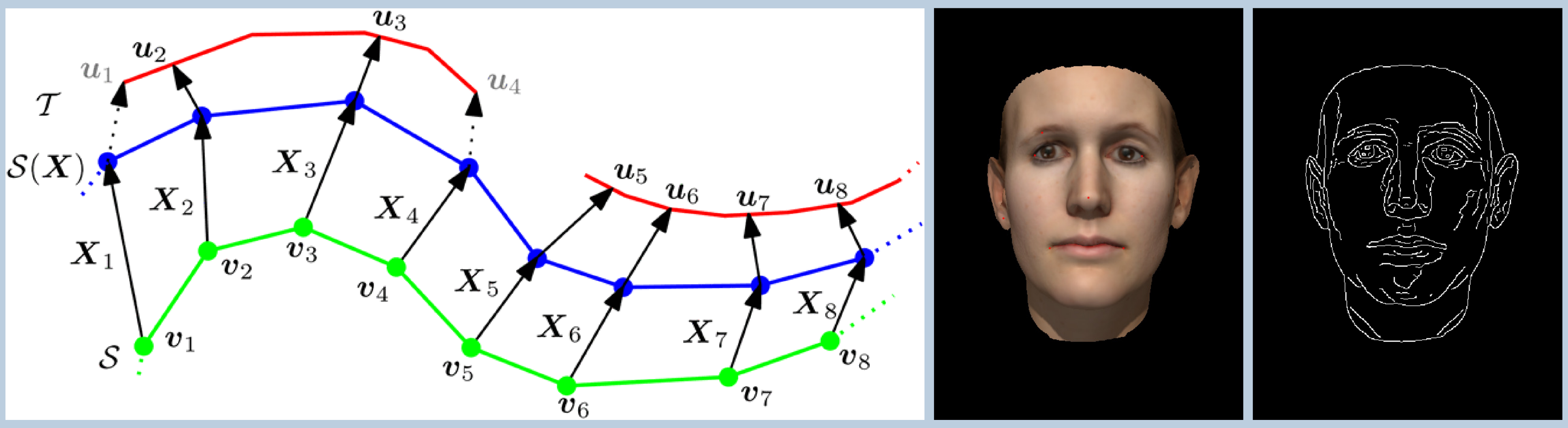
```
Initialize pose parameters;
for M iterations do
    Estimate pose parameters whilst
    keeping shape parameters fixed;
    Estimate shape parameters whilst
    keeping pose parameters fixed;
end
Perform non-linear bundle adjustment on
shape and pose parameters
simultaneously;
```

Source

The source code is available at `http://mimoza.marmara.edu.tr/~anil.bas/research/yorktalks2016/`

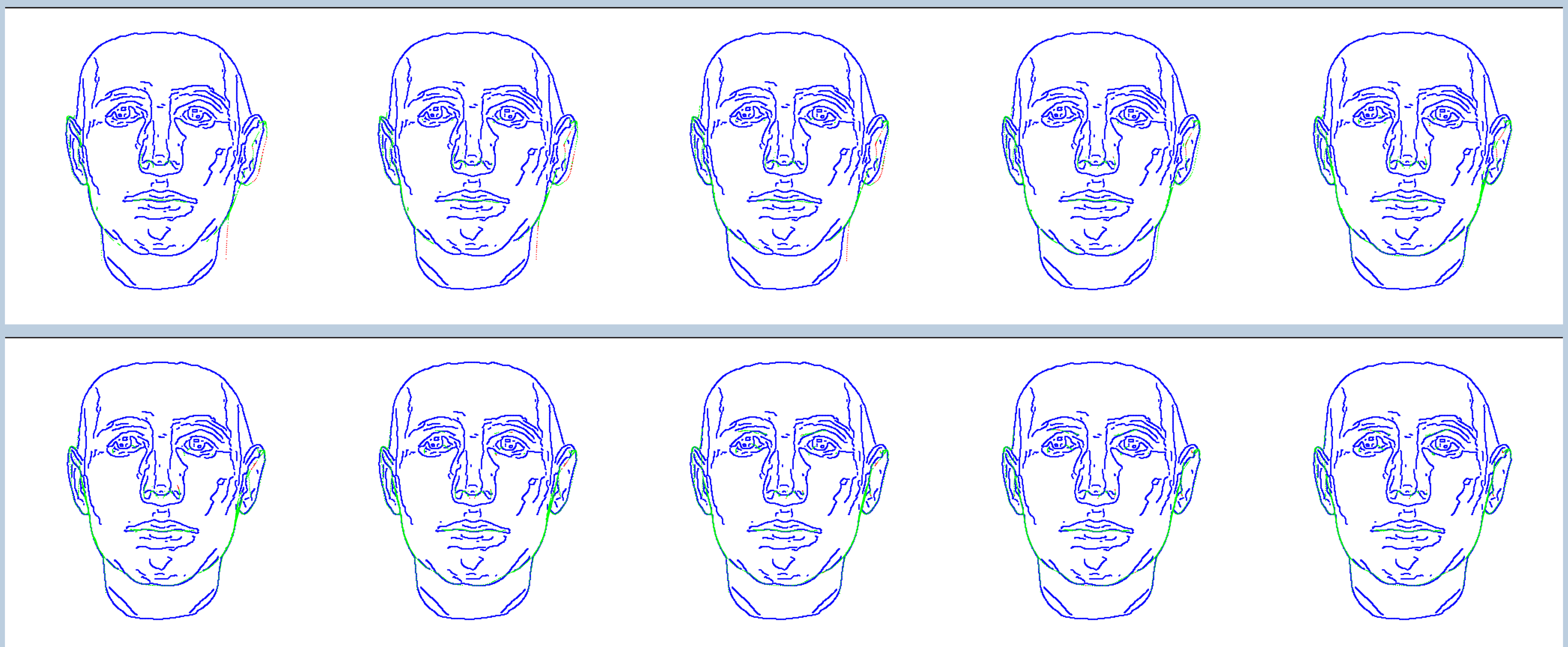
Method

Edges are an attractive feature to exploit because they are relatively insensitive to changes in illumination and camera parameters. They also convey shape and pose information in a rather direct manner.



Our approach is as follows:

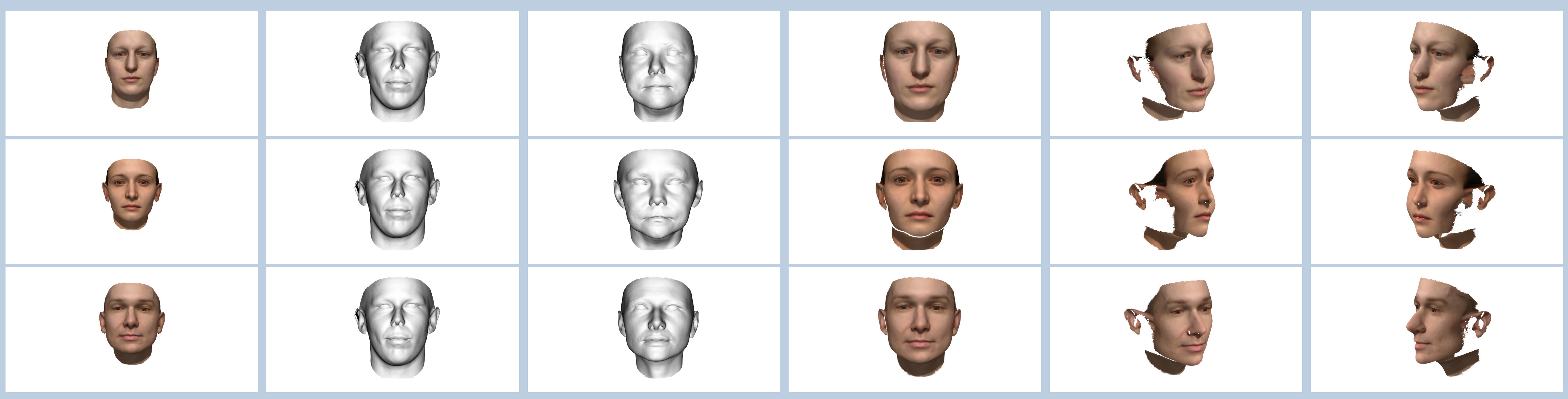
1. Compute a binary edge map from the input image.
2. Given an initial estimate of the shape and pose of the face, compute which vertices lie on the occluding boundary of the estimated shape.
3. For each projected edge vertex, find the closest image edge pixel. This can be done efficiently by storing the image edge pixels in a Kd-tree.
4. Filter the correspondences by removing matches where the distance to the closest edge pixel is larger than a threshold.
5. The edge correspondences provide new 2D landmarks. Return to step 2 with the new shape and pose estimates.



Results

We propose an approach inspired by the iterated closest point (ICP) algorithm, based on computing hard correspondences between model vertices and edge pixels. Three example scans from Basel Face Model fitted using our method are shown below.

Face Image | **Base Model** | **Fitted Model** | **Texture Sampling**



References

[1] Blanz, Volker and Vetter, Thomas, *A Morphable Model for the Synthesis of 3D Faces*, Computer Graphics Proc. SIGGRAPH '99, pp. 187-194, 1999.

[2] Amberg, Brian and Romdhani, Sami and Vetter, Thomas, *Optimal Step Nonrigid ICP Algorithms for Surface Registration*, IEEE Conference on Computer Vision and Pattern Recognition In CVPR'07, 2007.

[3] Paysan, Pascal and Knothe, Reinhard and Amberg, Brian and Romdhani, Sami and Vetter, Thomas, *A 3D Face Model for Pose and Illumination Invariant Face Recognition*, Proceedings of the 6th IEEE International Conference on Advanced Video and Signal based Surveillance (AVSS) for Security, Safety and Monitoring in Smart Environments, 2009.